

Original Article

Compensator-based Intensity-modulated Radiotherapy in Head and Neck Cancer: Our Experience in Achieving Dosimetric Parameters and their Clinical Correlation

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ABSTRACT:

Aims: To review the Batra Hospital and Medical Research Centre experience of using compensator-based intensity-modulated radiotherapy (IMRT) to treat head and neck cancer.

Materials and methods: Between October 2003 and August 2004, 18 patients underwent IMRT for head and neck cancer at our institution. IMRT was delivered using partial transmission high-resolution compensator blocks.

Results: With a median follow-up of 13.3 months, two patients had residual disease and two failed in the gross tumour volume (GTV). The complete response rate after surgical salvage was 94.5%. Both the locoregional relapse-free and disease-free survival rates were 81.8%. The target coverage in terms of average maximum, mean and minimum dose (in Gy) delivered was 78.6, 73.5 and 58.4 to the GTV—planning target volume, 82.3, 70.9 and 47.3 to clinical target volume 1 (CTV1) and 82.9, 66.2 and 29.6 to CTV2. The dose constraint of 30 Gy to less than 50% of the contralateral parotid volume was achieved in 12 (66.7%) patients. If the dose constraint was revised to 35 Gy, at least 50% of the parotid volume was spared in 17 (94.5%) patients. On average, 75% of the contralateral parotid volume received a dose less than 35 Gy in 13 (72.3%) patients with grade I xerostomia, whereas this was 49.3% in five (27.7%) patients with grade II xerostomia, and the difference was statistically significant ($P = 0.001$).

Conclusions: In our initial experience, compensator-based IMRT is feasible with regard to target coverage and parotid volume sparing. The parotid volume dose has significant clinical implications on the grade of xerostomia. Our results invoke rethinking into the issues of the parotid volume dose constraint in our subpopulation. Nangia, S. *et al.* (2006). *Clinical Oncology* 18, 485–492

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Key words: Compensator, head and neck cancer, intensity-modulated radiotherapy

Introduction

Intensity-modulated radiotherapy (IMRT) is finding increasing application in the treatment of head and neck cancer [1]. It allows parotid volume sparing, the delivery of high dose to target volumes that wrap around the spinal cord and sparing of dose-limiting structures such as the parotids, mandible, brainstem and cochlea. In addition, it obviates the need for electron boost to the posterior triangle and the problems arising from photon electron junction uncertainties. The basis of IMRT is the inverse planning technique varying fluence across the beam [2]. This varying fluence may be generated through a high-resolution physical compensator or by varying dwell times of individual leaves of multileaf collimators.

There has only been one study comparing multileaf collimator-based IMRT vs compensator-based IMRT and it showed no advantage of the former technique over the latter [3]. The investigators also highlighted some advan-

tages of compensator-based IMRT, namely, that it offers robustness, excellent intensity modulation resolution, high treatment delivery efficiency, simple fabrication and quality assurance procedures and flexibility, allowing its use in any teletherapy unit. Although technical issues have already been described [4,5], clinical feasibility with regard to target coverage, parotid volume sparing, xerostomia and local control has never been published. Such data will especially help hospitals with a linear accelerator with standard jaws upgrade to this form of IMRT for the additional cost of software and compensator cutting hardware.

Here, we describe our initial experience in implementing and achieving dosimetric parameters on a compensator-based IMRT system for head and neck cancer treatment. This is the only study evaluating the results of a compensator-based IMRT system, with regard to target coverage and parotid volume sparing, and clinical correlation in terms of xerostomia and locoregional control.

Materials and Methods

Between October 2003 and August 2004, 18 head and neck cancer patients were treated with IMRT in the Department of Radiation Oncology, Batra Hospital and Medical Research Centre, New Delhi, India. Before the enrolment of patients, the trial was approved by the hospital review board and clinical research committee. Written informed consent was obtained from each patient before his or her participation in the study. The treatment of 17 patients was definitive, whereas one patient was a postoperative case of cancer of the anterior border of the tongue who received radiation to the neck. The pre-treatment work-up included a complete history and physical examination, a direct flexible fiberoptic endoscopic examination, complete blood count, biochemistry, chest X-ray, pathology review, diagnostic computed tomography, magnetic resonance imaging scans where needed and a dental evaluation. Staging was carried out according to the American Joint Committee on Cancer (AJCC) 2003 classification [6].

Immobilisation, Simulation and Treatment Planning Computed Tomography Procedure

The neck and shoulder were immobilised with the help of an Orfit cast with the head in the neutral position. A simulation was carried out on a Verasim simulator. The probable isocentre was marked with radiopaque computed tomography markers. Treatment planning helical computed tomography with contrast was carried out on a Prospeed SX Advantage. A computed tomography scan with 2.5 mm thick slices was obtained from the head down through the clavicle and was transferred to our planning system.

Delineation of Target Volumes

The gross tumour volume (GTV) was determined on the basis of radiological evidence supplemented with clinical findings. Clinical target volume 1 (CTV1) was the area considered to be at a high risk of harbouring microscopic disease. The extent of CTV1 was GTV + 1.5 cm margin, except at anatomical barriers, where only the planning target volume (PTV) was taken. The margin was more than 1.5 cm where the mucosa was involved and the whole mucosa of that subsite was included. The PTV was taken as a 3 mm margin around the GTV, CTV1 and CTV2 and was named GTV-PTV, CTV1-PTV and Target, respectively. The planning software Plato RTS does not support two target volumes with the same name. Therefore, CTV2 and Target were marked as single target volumes including the area of interest in the ipsilateral as well as the contralateral neck. Initially, the nodal target was drawn according to Gregoire *et al.* [7] and the inclusion of nodal levels was dependent on the primary site and whether the neck was clinically positive or negative. After publication of the Radiation Therapy Oncology Group (RTOG) guidelines [8], the CTV2 volume was changed accordingly, with some modifications for the clinically positive neck and the postoperative neck. Retropharyngeal lymph nodal regions, lymph nodes at

levels I–V and the supraclavicular nodes are routinely covered for all nasopharyngeal cases. Nodal regions were treated if the chance of involvement of the malignant process was more than 6%. According to new RTOG consensus guidelines [8], level II was taken up to the caudal edge of the lateral process of C1 except in cases of a node-positive neck where it was extended to the base of the skull on the same side where the neck was positive [9].

Treatment Planning, Evaluation and Delivery

Plato RTS version 2.5.2 was used as the planning software. This system carries out dose optimisation with inverse planning using the gradient search algorithm. Treatment was delivered using compensator blocks fabricated in an Autimo 2.5 D cutter. A drill bit size of 6 mm was used, which gives a resolution in pixels of 6 mm and a width at the isocentre of 10.53 mm. The plans generated were assessed for coverage of the target volumes. The indices used are defined in Table 1. Dose–volume histograms generated by Plato RTS do not subtract high-dose prescription volumes contained in the larger volumes. For example, the dose–volume histogram for CTV1 will not exclude the dose to GTV–PTV. This emphasises the importance of reviewing the isodoses in every computed tomography slice. The alloy used for making compensators was a mixture of bismuth (52%), lead (30%) and tin (18%). Treatment was delivered on a Siemens Mevatron MD2 Linear Accelerator. For quality assurance, Kodak EDR-2 dosimetric films were used. Digitally reconstructed radiographs were generated and checked against the simulator or port film. Details of quality assurance will be published subsequently.

Treatment

All patients received electron beam radiation therapy in the form of IMRT for the primary and upper neck, whereas the lower neck and supraclavicular fossa were treated with the single direct anterior field with split beam technique. The prescribed dose was 70 Gy to the GTV and positive neck nodes, except in one postoperative patient where the dose was 66 Gy in 30 fractions. The adjacent area surrounding the GTV, with a high index of suspicion for harbouring microscopic disease (GTV + 1.5 cm margin), was named CTV1 and the prescription dose was 66 Gy. CTV2 encompassed the clinically negative neck with more than a 6% chance of harbouring microscopic disease and was treated with 56 Gy. The dose per fraction for the GTV, CTV1 and CTV2 was 2, 1.88 and 1.6 Gy, respectively. Concurrent chemotherapy in the form of cisplatin or carboplatin was given. Patients suffering from carcinoma of the nasopharynx underwent adjuvant chemotherapy after IMRT.

Response Assessment, End Points and Statistics

The patients were followed weekly during the treatment. The response and treatment-related toxicities were

Table 1 – Dosimetric parotid and tumour coverage parameters

Target coverage parameter				
	Average dose	V _{95%}	V _{93%}	D ₂ /D ₉₈
Ideal coverage	±3 Gy of prescribed dose	≥ 98%	≥ 99%	≤ 1.15
Acceptable	±5 Gy of prescribed dose	≥ 95%	≥ 98%	≤ 1.20
Parotid volume sparing parameter				
	Average dose	V _{30 Gy}	D _{20 ml}	
Ideal sparing	≤ 30	50%	≤ 20 Gy	
Acceptable	≤ 32	50%	≤ 25 Gy	
Critical structure parameter				
	Spine (V _{45 Gy})	Mandible (V _{60 Gy})	Brainstem (V _{54 Gy})	
Ideal sparing	≤ 1%	≤ 10%	0%	
Acceptable	≤ 5%	≤ 15%	≤ 1%	

V_{X%}, the percentage volume of target receiving X% of prescribed dose; D₂/D₉₈, the ratio of dose received by 2% of the target and 98% of the target. V_{X Gy}, the percentage volume of organ receiving more then or equal to X Gy of dose; D_{20 ml}, the dose received by 20 ml combined volume of both parotids.

quantified by clinical and radiographic examinations (contrast-enhanced computed tomography). After completion of the treatment, the evaluation was carried out on a monthly basis for the first 6 months, then every 2 months for the next year. Acute and late normal tissue effects were graded according to the RTOG radiation toxicity morbidity scoring criteria. The response evaluation was carried out according to World Health Organisation criteria [10], at 6 weeks after the completion of radiotherapy. Primary site and lymph node responses were scored separately, and the overall response was determined according to the site showing the lesser response 6 weeks after the completion of treatment. A complete response was defined as the disappearance of all clinically or radiographically evident tumours. A partial response was defined as a reduction of greater than 50% in the product of the two greatest perpendicular diameters of all measurable disease. No response was defined as any response less than a partial response and progressive disease was defined as an increase of greater than 25% in the product of the two greatest perpendicular diameters of all measurable disease. If there was residual disease, patients were referred to the surgical oncology clinics for assessment of surgical intervention. The primary end points for this study were dosimetric parotid volume sparing, tumour coverage (Table 1), overall response, locoregional relapse-free survival (LRFS), treatment morbidity having an effect on total treatment time and treatment-related mortality. The secondary end points were subjective parotid sparing assessed in terms of different grades of xerostomia as per RTOG toxicity criteria, disease-free survival (DFS) and overall survival. The data were analysed using the SPSS version 10 statistical software. Time for end points was calculated from the date of registration. Descriptive statistics in terms of mean, median, proportions and standard deviation were calculated. In a detailed analysis, after defining the grouping

variables, an independent t test was carried out to highlight the differences within each group. Time-dependent variables were analysed using Kaplan–Meier methods. Events for LRFS included the first recurrence of disease at a local or regional site or persistent disease. Persistent disease was regarded as a failure on the last date of radiotherapy. Events for DFS included first recurrences at a local, regional or distant site and death because of disease, that is disease was present at the time of death. Events for overall survival included all deaths. All the patients who were lost to follow-up, with or without disease, were counted as events and the time to event was their last follow-up visit.

Results

Patient and Tumour Characteristics

In total, 18 patients were treated with IMRT for head and neck cancer from October 2003 to August 2004. There were 16 men and two women with a mean age of 63.4 years. The distribution of patients according to site was larynx 10, tonsil two, nasopharynx two, hypopharynx one, anterior tongue two and base of tongue one. All patients had histopathology reported as squamous cell carcinoma (SCC), with seven patients with well-differentiated SCC, five patients with moderately differentiated SCC and six patients with poorly differentiated SCC. There were nine patients with positive neck nodes. The T stage distribution was as follows: seven patients each with T2 and T3 and three patients with a T4 tumour. The average tumour volume was 67.75 ml (range 9.9–160.50 ml).

Treatment Outcome

All patients completed treatment, with a mean overall treatment time of 53.4 days (standard deviation ± 4 days)

and range 44–57 days. Concurrent chemoradiotherapy was given in 14 patients. One patient with carcinoma of the larynx received neoadjuvant chemotherapy and another patient with carcinoma of the nasopharynx received three cycles of adjuvant chemotherapy (cisplatin and 5-fluorouracil) after receiving concurrent chemotherapy (cisplatin 80 mg/m²) at 0, 21 and 42 days with IMRT. Of 14 patients from the chemoradiotherapy group, five patients received cisplatin, whereas eight patients received carboplatin as concurrent chemotherapy because of either decreased creatinine clearance or baseline hearing loss on audiometry. The complete response rate was 88.9%. Of 18 patients, two had residual disease, one at the primary site and the other at a nodal site. The patient with nodal residual disease underwent radical neck dissection and the nodes were negative for malignant cells. With the median follow-up of 13.3 (standard deviation \pm 5.4) months, two patients recurred at the primary site 9 and 6 months after the completion of treatment. The site of recurrence corresponded with the high-dose volume (66–60 Gy). One patient recurred in the supraclavicular region, which had not been incorporated in the IMRT field but had received 50 Gy by a single anterior field. The overall response rate after surgical salvage was 94.5%. Overall, of 18 patients, 14 are alive without disease, whereas two are alive with disease and two were lost to follow-up with disease. The patient with a primary oral tongue tumour had residual disease and was advised surgery, whereas the patient who recurred at 9 months was lost to follow-up with disease. The patient who recurred at 6 months is still on follow-up and is alive with disease. Although a median follow-up of 13.3 months is too short to comment on survival, the overall locoregional control is comparable with conventional treatment. One year LRFS (Fig. 1) and DFS were both 81.8%. The median LRFS time was not reached, whereas the mean LRFS time was 17 months (95% confidence interval 14.6, 19.4). A subjective feeling of xerostomia (grade II)

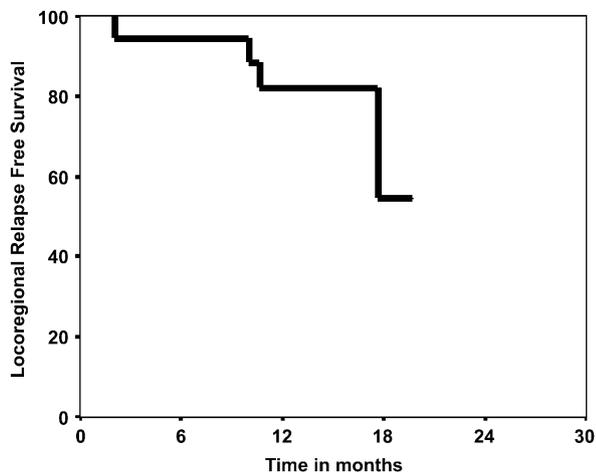


Fig. 1 – Kaplan–Meier survival curve showing locoregional relapse-free survival (LRFS) for the entire study population. The median LRFS time was not reached and the mean LRFS time was 17 months (95% confidence interval 14.6, 19.4).

was present in five (27.8%) patients and 13 (72.2%) patients had occasional xerostomia not affecting their normal feeding pattern (grade I).

Dose Volume Analysis

The target coverage for 16 patients where the prescription was 70 Gy in 35 fractions in terms of average maximum, mean and minimum dose (in Gy) delivered was 78.6 (\pm 4.7), 73.5 (\pm 2.0) and 58.4 (\pm 6.7) to the GTV, 82.3 (\pm 2.6), 70.9 (\pm 2.6) and 47.3 (\pm 7.2) to CTV1 and 82.9 (\pm 2.3), 66.2 (\pm 3.0) and 29.6 (\pm 10.1) to CTV2. An average of 2% of the GTV, 8.2% of CTV1 and 5.9% of CTV2 received less than 95% of the prescribed dose. For postoperative patients, the prescription dose was 66 Gy in 33 fractions and the average maximum, mean and minimum doses (in Gy) delivered were 82.9 (\pm 3.4), 70.6 (\pm 4.5) and 38.5 (\pm 5.2) to CTV1 and 82.5 (\pm 3.5), 65.6 (\pm 6.4) and 28.6 (\pm 5.3) to CTV2. An average of 3.9% of CTV1 and 4.7% of CTV2 received less than 95% of the prescribed dose. On average, 110% of the prescribed dose was received by 15% (\pm 4.1) of the GTV. It should be noted that the maximum and minimum doses are the point doses, although the maximum dose described by the International Commission on Radiation Units and Measurement report no. 50 is the region encompassed by a 2 cm area. Details of dose coverage for the GTV, CTV1 and CTV2 are given in Table 2.

With regard to normal tissue doses (Table 3), there was significant sparing of all critical structures without compromising tumour target coverage. The dose to these critical organs would be significantly higher if conventional radiotherapy was used. Parotid volume doses were correlated clinically with subjective salivary gland function. Grade I xerostomia was present in 11 patients where the average volume of parotid receiving less than or equal to 20 Gy dose was 9 ml (\pm 8.4), whereas in patients with grade II xerostomia it was 0.7 ml (\pm 0.6). This difference was statistically significant ($P = 0.004$). In 12 (66.7%) patients, 30 Gy or more was delivered to less than 50% of the contralateral parotid volume; when the dose constraint was raised to 35 Gy, the parotid was spared in 17 (94.5%) patients. Details of parotid volume doses are given in Table 4. Acute side-effects of radiation therapy with concurrent chemotherapy were well tolerated. The most common toxicity was grade III mucositis (64.4%) and/or pharyngitis (44.5%). None of the patients had grade III or IV skin reactions or haematological toxicity. Seven patients required nasogastric intubation for some part of their treatment, to ensure adequate nutrition. The most common side-effect was xerostomia, which seemed to decrease with time after IMRT. Grade I salivary gland toxicity was present in 13 patients, whereas five patients had grade II salivary gland toxicity.

The subgroup analysis (Table 5) revealed that increasing the volume of the GTV had a negative effect on its coverage. The parotid volume sparing was directly related to grade I xerostomia (Table 5). The above-mentioned differences were statistically significant ($P < 0.05$). The volume of parotid receiving less than or equal to a 35 Gy dose had a statistically significant effect on the status of

Table 2 – Target dose volume data

	V ₁₀₀ ± SD	V ₉₅ ± SD	V ₉₃ ± SD	Average dose	D _{2/98}
GTV (95% CI)	89.3 ± 6.7 (84.4, 94.1)	98 ± 1.2 (97.1, 98.8)	98.9 ± 0.8 (98.3, 99.4)	73.7 ± 2.3 (72.1, 75.3)	1.18
CTV1 (95% CI)	83.2 ± 12.3 (74.4, 92)	91.8 ± 7.3 (86.6, 97.1)	93.9 ± 5.8 (89.7, 98)	70.8 ± 2.5 (69.6, 72.1)	NA
CTV2 (95% CI)	89.5 ± 8.2 (83.7, 95.5)	94.1 ± 5.2 (90.4, 97.8)	96.2 ± 4.0 (93.4, 99.1)	66.1 ± 2.8 (64.7, 67.6)	NA

GTV, gross tumour volume; CTV, clinical target volume. V₁₀₀, V₉₅ and V₉₃ represent the percentage of volume receiving 100, 95 and 93% of the prescribed dose, respectively. SD, standard deviation; CI, confidence interval; NA, not applicable (our planning software does not allow calculation of CTV1 and CTV2 doses independently after subtracting GTV from CTV1 and CTV1 from CTV2. That is why average doses of CTV1 and CTV2 are much higher than the doses prescribed).

xerostomia (Table 5), whereas none of the other parotid dose constraints (average dose, volume of parotid receiving 28 and 30 Gy) influenced xerostomia significantly.

Discussion

IMRT results in a high conformal dose distribution, which emphasises the need for accurate target delineation. There are various guidelines pertaining to the delineation of the nodal target volume in the head and neck region [7,8,11–17]. A complete atlas of contrast-enhanced computed tomography sections depicting anatomical boundaries of the CTV encompassing various node levels from the base of the skull to the level of the sternoclavicular joints has been posted on the DAHANCA (<http://www.dshho.suite.dk/dahanca/guidelines.html>), EORTC (<http://groups.eortc.be/radio/EDUCATION.htm>) and RTOG (<http://www.rtog.org/hnatlas/main.htm>) websites. We followed the RTOG consensus guidelines [8] with some modifications for node-positive and the postoperative neck. These nodal atlas guidelines are helpful to the radiation oncologist in delineating the CTV during treatment planning. However, these atlases, whether anatomy based [12,13] or imaging based [14–17], primarily focus on delineation of the lymph node levels for the normal neck. Distortions of the normal head and neck anatomy may occur when there is surgical violation or when there is gross disease involvement of adjacent tissues such as muscles. In this study, the CTV definition was very generous because of concerns of marginal failure. The margin around the GTV for potential direct routes of microscopic spread was taken as 1.5 cm or more as and when required.

Chao *et al.* [18] reported their experience of 126 head and neck cancer patients treated with IMRT and proposed guidelines for target volume determination and delineation. Their guidelines were based on the location of the primary tumour site and its probability of microscopic metastasis to the ipsilateral and contralateral (levels I–V) lymph nodal regions. For primary cases, CTV1 included the gross tumour and the region adjacent to the tumour but not directly involved by the tumour, whereas CTV1 in the postoperative cases included the pre-operative GTV plus a 2 cm margin. CTV2 for both the definitive and postoperative cases encompassed the uninvolved cervical lymph nodal regions. The CTV was larger in patients with gross nodes or those

with extracapsular extension than in those patients who did not have gross nodal involvement or extracapsular extension in both the primary and postoperative cases, respectively. With a median follow-up of 26 months, there were six (of 52; 12%) definitive cases with persistent or recurrent nodal disease and seven (of 74; 9%) postoperative cases with failure in the nodal region. There was only one failure marginal to CTV1, but this was an in-field failure of CTV2. There were two failures marginal to CTV2. Our target volumes were also liberal, especially for CTV2 (prophylactic nodal irradiation). For CTV1, our margin around the GTV was 1.5 cm, but was extended if potential for microscopic disease lay outside that volume. For base of the tongue lesions, CTV1 margins were modified to include vallecula and, similarly for laryngeal and hypopharyngeal lesions, the entire laryngeal apparatus was included within CTV1. Of 18 patients, three had recurrence and two had residual disease during a median follow-up of 13.3 months. Overall recurrence for this short follow-up period was 17.6%.

Radiation therapy for head and neck cancer can profoundly affect quality of life [19–23]. Xerostomia affects every aspect of life, including speech, nutrition, taste and sleep, and serves to remind patients of their illness and its treatment long after both have been dealt with. The subjective assessment of salivary gland function is an important criterion to consider when delivering definitive radiation therapy for head and neck cancer. In our study, we aimed to deliver 30 Gy to less than 50% of the contralateral parotid volume. Wherever possible we also attempted to achieve this dose constraint for the ipsilateral parotid volume and were successful in six patients for the ipsilateral parotid volume and in 12 patients for the contralateral

Table 3 – Normal tissue dose constraint and their achieved values

Critical organ	Volume in percentage (±standard deviation)
Spine V ₄₅ Gy	6.7 ± 7.8
Spine V ₅₀ Gy	1.5 ± 2.6
Mandible V ₆₀ Gy	17.7 ± 10.8
Brainstem V ₅₄ Gy	5.8 ± 12.8
Ipsilateral parotid V ₃₀ Gy	74.5 ± 26.5
Contralateral parotid V ₃₀ Gy	47.9 ± 21.1

Table 4 – Parotid dose volume data

Parotid	Volume (ml)	V _{28 Gy} (%)	V _{30 Gy} (%)	V _{35 Gy} (%)	Average dose (Gy)	Maximum dose (Gy)	Minimum dose (Gy)	V _{20 Gy} (ml)*
Ipsilateral ± SD	21.2 ± 8.7	77.7 ± 24.8	74.5 ± 6.5	63.9 ± 30.5	39.4 ± 12.4	70.9 ± 7.5	16.7 ± 12.4	6.7 ± 8.1
Contralateral ± SD	19.9 ± 6.9	55.2 ± 21.9	47.9 ± 21.1	28.9 ± 15.5	28.7 ± 5.5	61.5 ± 7.4	8.8 ± 7.9	

SD, standard deviation. *Combined parotid volume that receives a dose of 20 Gy or less.

parotid volume. In a study by Lin *et al.* [23], which assessed subjective salivary gland function using a questionnaire, dosimetric sparing of the parotid volumes improved subjective xerostomia. In our study, dosimetric parameters for parotid volumes were also correlated significantly with the subjective feeling of dryness (Table 5).

Clark *et al.* [24] studied the potential of IMRT to improve the coverage of the targets and the sparing of the spinal cord in radiotherapy treatment of the larynx and bilateral cervical lymph nodes in patients with advanced larynx cancer. Their dose prescription was 65 Gy in 28 fractions for the larynx PTV, whereas for the nodal PTV it was 50 Gy, that is 2.32 Gy per fraction for the larynx PTV and 1.8 Gy per fraction for the nodal PTV. For the larynx PTV, the averages of the minimum, mean and maximum doses (in Gy) were 62.1 (±0.7), 64.8 (±0.1) and 66.7 (±0.6) and for the nodal PTV 46.8 (±0.5), 50.7 (±0.5) and 57.8 (±2.8). Chao *et al.* [18] investigated the feasibility and optimisation of tomotherapy-based IMRT in patients with head and neck cancer. In their best achievable plan, only 27 ± 8% of parotid gland volumes were treated to more than 30 Gy, whereas an average of 3.3 ± 0.6% of the target volumes received less than 95% of the prescribed dose. The

minimum, mean and maximum doses (in Gy) to the GTV were 44.77 ± 11.93, 72.49 ± 1.66 and 79.40 ± 2.2 whereas for the contralateral parotid volume the minimum, mean and maximum doses (in Gy) were 8.8 ± 7.9, 28.7 ± 5 and 61.5 ± 7.4.

Lee *et al.* [25] reported their experience using IMRT for head and neck cancer. The prescribed dose was 70 Gy to the GTV and positive neck nodes, 60 Gy to the CTV, which included the GTV plus a margin of potential microscopic disease, and 50–60 Gy to the clinically negative nodal regions. The dose for the CTV was 1.8 Gy/fraction/day, 5 days a week, whereas the GTV received a higher dose per fraction, that is 2.12 Gy/fraction/day. The average maximum, mean and minimum doses (in Gy) delivered were 80, 74 and 56 to the GTV and 80, 69 and 33 to the CTV. An average of only 3% of the GTV and 3% of the CTV received less than 95% of the prescribed dose. The mean left and right parotid volume doses were both 29 Gy. In our series, the target coverage was achieved in all the patients within the defined dosimetric limits and all the dosimetric parameters were comparable with the above-mentioned studies [18,24,25]. Target coverage in terms of average maximum, mean and minimum doses (in Gy) delivered was

Table 5 – Subgroup analysis studying the effect of various variables on gross tumour volume (GTV) coverage, parotid volume sparing and grades of xerostomia

GTV volume and its coverage			
V _{95%} GTV	Number of patients	Average GTV volume (ml)	Significance (two-sided t test)
≥ 98%	9	39.2 ± 22.9	0.009
< 98%	8	94.6 ± 49.6	
V _{93%} GTV	Number of patients	Average GTV volume (ml)	Significance (two-sided t test)
≥ 99%	10	41.4 ± 22.7	0.006
< 99%	07	99.4 ± 51.6	
Analysis of xerostomia in relation with various dosimetric parameters			
	Grade I xerostomia (n = 13)	Grade II xerostomia (n = 5)	Significance (two-sided t test)
V _{35 Gy} parotid	25.2 ± 9.8%	50.7 ± 16.3%	0.001
V _{20 Gy} parotid	9 ± 8.4 ml	0.7 ± 0.6 ml	0.004
D _{1/3V} parotid	31.1 ± 4.5 Gy	37.7 ± 6.6 Gy	0.026

V_{93%} GTV, average value of percentage volume of GTV receiving 93% of the prescribed dose; V_{35 Gy} parotid, average value of contralateral parotid volume percentage receiving a dose of 35 Gy or more; V_{20 Gy} parotid, average value of combined parotid volume (in ml) receiving a dose of 20 Gy or less; D_{1/3V} parotid, average value of dose (in Gy) received by one-third volume of contralateral parotid.

78.6 (± 4.7), 73.5 (± 2.0) and 58.4 (± 6.7) to the GTV, 82.3 (± 2.6), 70.9 (± 2.6) and 47.3 (± 7.2) to CTV1 and 82.9 (± 2.3), 66.2 (± 3.0) and 29.6 (± 10.1) to CTV2. The average dose for CTV1 and CTV2 seems to be very high and the reason for this is that our planning software does not have the option of subtracting overlapping volumes. When calculating the average dose to CTV1 and CTV2 the system also incorporates the dose to the GTV, thus increasing the overall average dose.

Dosimetric parameters were achieved in 13 patients for the contralateral parotid volume and the average mean dose for all 18 patients was 28.7 ± 5.5 Gy (range 17.2–41.3). The average dose to the ipsilateral parotid volume was 39.4 ± 12.4 (range 25.4–59.6). Although the mean parotid volume dose in our study was higher than in the above-mentioned studies, we were able to achieve other parameters in most of our patients (Table 4). The average mean dose to one-third volume of the parotid in patients with grade I xerostomia was 31.1 Gy, whereas it was 37.7 Gy in patients with grade II xerostomia and the difference was statistically significant ($P = 0.026$). All dosimetric parameters for the contralateral parotid volume were achieved except one, namely the combined 20 ml volume of both parotids ($D_{20\text{ ml}}$) should receive less than or equal to a 20 Gy dose. In our subpopulation, the average total parotid volume was 43.8 ± 16.1 ml (range 19–69.8 ml). On retrospective analysis, the total parotid volume receiving 20 Gy or less was 9 ml in the 13 patients with grade I xerostomia and 0.6 ml in the five patients who reported grade II xerostomia. This difference was statistically significant ($P = 0.004$). In future, we plan to include objective parotid function and to study the relationship between dose volume parameters and objective and subjective assessment of parotid function. Similarly, $V_{30\text{ Gy}}$ and $V_{28\text{ Gy}}$ had no significant effect on xerostomia, whereas $V_{35\text{ Gy}}$ was significantly different in patients with grades I and II xerostomia (Table 5). These findings are provocative. The feasibility of target coverage and dosimetric parotid sparing has been assessed and future protocols would emphasise parotid sparing with regard to these new findings. Reviewing published studies, there are no published data on compensator-based IMRT with reference to dosimetric parameters in relation to clinical outcome. It is not feasible to compare our results with reference to multileaf collimator-based IMRT systems, because optimisation is limited by the maximum thickness of compensator blocks (4.5 cm). This may explain the inverse relationship between the target coverage and volumes of the GTV (Table 5). CTV2 coverage was directly related to parotid volume sparing (Table 5). It is worth mentioning here that despite under-dosage in the CTV2 volume adjacent to the medial aspect of the parotid, there were no failures in this area.

In conclusion, compensator-based IMRT was feasible in terms of target coverage and parotid volume sparing. The results were satisfactory in a substantial number of patients. This was our initial experience and we were able to achieve our dosimetric parameters in a substantial number of patients. On reviewing our results, we are comfortable using this approach and our future protocols

will include subjective as well as objective analyses of parotid gland function.

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